PUBLICATIONS.

Summary of Current pre-Cambrian North American Literature.[1]

Smith,[2] in 1892, reports on the Archean Rocks of Hunters Island and adjacent country. The rocks are divided into Laurentian and Huronian, and the latter subdivided into Coutchiching and Keewatin. The main occurrences of the Laurentian rocks are the Kawagansikok, Poo-Bah, Hunters Island and Saganaga areas. The Kawagansikok granite is in places fine grained and nearly devoid of mica and hornblende; in other places is a muscovite-granite; in others is garnetiferous granite-gneiss. The rock is frequently cut by coarse pegmatite veins. The Poo-Bah area is usually a coarse hornblende syenite, but in places it merges into a finer grained hornblende-granite. The Hunters Island rocks are usually biotite-granites, but the biotite is often replaced by, or associated with muscovite, hornblende or chlorite. At Agnes Lake angular fragments of Mica-schist or gneiss are found in the granite. At various places occur hornblende-granites. There are other isolated areas of granite which break through the Coutchiching rocks which cannot certainly be said to be of Laurentian age. The granites as a whole usually have a foliated character.

The Coutchiching series covers a large area in the northwestern part of the district, and several small areas are found to the eastward. The Couchiching rocks are usually mica-schists. In general their schistosity is parallel to that of the granites, but at Conmee Lake there is a discrepancy between the two which may indicate a structural unconformity or a fault. The mica-schist is cut by granite apophyses at various places. If foliation is taken as thickness the series would vary from 1.386 miles to 5.548 miles. However the mica-schists are regarded as repeated by folding. Although having isoclinal dips, there is a considerable variation which may indicate such folding.

Keewatin rocks are confined to the southeastern part of Hunters Island. They consist of quartzites, soft gray schists, quartz-porphyries,

[1] Continued from p. 236, Vol. III. JOURNAL OF GEOLOGY.

[2] Report on the Geology of Hunters Island and Adjacent Country, by W. H. C. SMITH. Ann. Rep. Geol. Sur. of Canada, for 1890–1, Vol. V., Part 1, G., pp. 5–76, 1892.

felsite, sericite-schists, conglomerates, altered traps, hornblende-schists and other green schists. Occasionally contained in them are areas of banded jasper and hematite. On the north side of Cache Bay is a felsitic conglomerate in contact with a coarse-grained hornblende-granite. Beds of dolomite are associated with this conglomerate. The breadth of the Keewatin series gives no certain criterion by which to estimate its thickness. The dip shows an apparently simple synclinal structure.

As to the relations of the Laurentian to the Huronian series, they have a general parallel schistosity, and there are many phenomena suggestive that the granitic and syenitic type is of igneous eruptive origin, later than the Huronian, but the hornblendic and micaceous phases of these granites may be rocks of different determinable ages, the discovery of which may throw light not only on the genesis of the Laurentian, but on its relations to the overlying Couchiching and Keewatin. Cutting both Laurentian and Couchiching rocks are diabase dikes in such attitudes as to leave little doubt that they were intruded since the last folding, on which assumption their geological age is post-Keewatin.

Grant,[1] in 1894, gives a general account of the geology of the Gunflint lake district. In Ts. 65 and 66 N., Rs. 4, 5 and 6 W., are Keewatin rocks, including the usual types—volcanic tuff, greenstone-schists, greenstone, and the Ogishke conglomerate. The Saganaga granite is intrusive in the Keewatin. The more crystalline schists of the district have been called Couchiching and Vermilion. It, however, appears that these rocks in this area are a more crystalline phase of the Keewatin, and that they owe their crystalline nature to the proximity of intrusive granite.

The iron-bearing rocks of Akeley Lake lie upon the Keewatin greenstone to the north, and on the south are overlaid by the great gabbro mass. The belt has a width of from 300 to 1300 feet, and a dip varying from 20° to almost vertical, but averaging 45° to 50°. Where widest, it has an average dip of 30°, which would make a maximum thickness of 650 feet. The iron ore is a titaniferous magnetite.

The Animikie rocks are little disturbed, except locally, having an

[1] Preliminary Report of Field Work during 1893 in Northeastern Minnesota, by U. S. GRANT, 22d Ann. Rep. Geol. and Nat. Hist. Sur. of Minn, Part IV., pp. 67–78, 1894.

average dip of 8° or 10° a little east of south. The Animikie beds are interleaved with diabase sills. These give parallel east and west ridges, the south sides of which are gentle slopes, and the north steep mural descents. This topography has led Lawson to the conclusion that the apparent large number of sills are due to monoclinal faulting of fewer layers, but of this there is no evidence. The Animikie strata are divided as follows: an upper or graywacke-slate member, 1900 feet thick, composed of slates and graywackes, with fine-grained quartzites and quartz-slates; a middle or black slate member, 1050 feet thick, composed mainly of black slates, apparently carbonaceous, with a fine grained siliceous and flinty layer at the base 60 feet thick; and a lower or iron-bearing member, composed largely of jaspery, actinolitic, siliceous and magnetitic slates, usually thinly laminated, and some beds of cherty iron carbonate. The Akeley Lake rocks, first called Pewabic quartzite, are similar to the Gunflint iron-bearing rocks and different from the Pewabic quartzite of the western Mesabi range, and if these iron-bearing rocks are put at the base of the Animikie, there seems to be serious objection to regarding them as the basal quartzite, and the equivalent of the quartzite of the western Mesabi range. No true quartzite is found at the base of the Animikie in the Akeley Lake area, but the iron-bearing rocks at Gunflint Lake rest directly upon the Keewatin.

The quartzites of Pigeon Point are lithologically similar to the quartzite at the top of the graywacke-slate member, and are supposed to be equivalent to it. The igneous rocks are all intrusive. The diabase sills sometimes have a thickness of 100 feet. They have not been found in contact with nor to extend into the gabbro below. The great Keweenawan gabbro of the district has a varying mineralogical composition, sometimes being composed almost entirely of feldspar, thus forming anorthosite, and again being exceedingly rich in olivine. This gabbro includes fragments of the Animikie slates, and was found directly overlying and in contact with the uppermost member of the Animikie, thus showing it to be of post-Animikie age. Associated with the coarse-grained gabbros are finer grained rocks including gabbros, olivine-gabbros, norites and olivine-norites, which have been called muscovado. These are slightly older than the main mass of gabbro, which is seen cutting and including fragments of them.

The acid eruptive rocks, called augite-syenite by Irving, including reddish, hornblendic, granitic rocks, are found cutting the gabbro. In

passing toward the granitic rocks, at first a few small acid dykes are seen. These increase in frequency in approaching the central mass of the granite, and at the edge of the mass apophyses can be traced directly from the granite into the gabbro. The dykes are not finer grained as a whole or at their edges, than the main mass, thus indicating the heated condition of the gabbro when the dykes were intruded. It is concluded that while the granite is of later date than the gabbro, it is not much later, and was perhaps intruded before the complete solidification of the basic rock.

Culver,[1] in 1894, describes the rocks of Itasca county, Minn. The Pokegama quartzite was found to extend from the north end of Pokegama Lake northeasterly to the rapids of Prairie River. This rock is flat lying, with low southerly or southeasterly dip, and seems to have been bowed into a series of low flat arches. The lower beds are fine grained, hard and massive, although broken into cubical blocks. In the upper portions of the quartzite in many places is found a considerable quantity of iron ore. In cross section there are alternately sheets of ore and sheets of quartz. In the hand specimen these quartz layers show no grains. The structure is porous, and the quartz is usually stained red. Both the ore and quartz layers are exceedingly irregular, and are often interrupted or cut by each other.

The Prairie River granite lies in a belt parallel to the Pokegama quartzite. It contains some bodies of schist, which are taken to indicate that the granite is eruptive. Thrust planes are numerous, and generally have either vertical or very steep dips.

On Big Fork River, a few miles above the mouth of Rice River, diorite was found, and also at Koochiching Falls in the Rainy River. Greenstones constitute the chief exposures between Rice River and Big Falls. They comprise beds which are purely eruptive, other beds which are consolidated tuffs, and other phases which it is not possible to place certainly in either class. The mica-schists constitute an immense series, extending on the Big Fork River from a point twelve miles below Little Falls to within fifteen miles of Rainy River. At various places the mica-schist is cut by granite. In passing from the mica-schist to the granite, the mica-schist becomes veined with a granite, which gradually increases in

[1] Notes on the Geology of Itasca county, Minn., by G. E. CULVER. Geol. and Nat. Hist. Sur. of Minn., 22d Ann. Rep., Part VIII., pp. 97–114, 1894.

abundance, until granite becomes the predominating rock. The schists are also cut by dikes of greenstone.

Elftman,[1] in 1894, publishes his field notes on Northeastern Minnesota. In the region north of Snowbank Lake are found conglomerate, mica-schist, sericite-schist, argillite, diabase, conglomeratic greenstone, porphyry, augite-granite and hornblende-granite. The former of these granites has heretofore been called gray syenite, and the latter red syenite.

On the west shore of Boot Lake, in the S.W. ¼, N.W. ¼, Sec. 21, T. 64 N., R. 8 W., are several large dykes of porphyry cutting the graywacke and schist. In the S.W. ¼, N.E. ¼, of the same section, on the east side of a long point, dikes of granite are found cutting the conglomerate in all directions, and distorting the strata in a very complicated manner. In the conglomerate are bowlders up to four feet in diameter of gneiss, slate, diabase and granite, the last being scarcely distinguishable from the granite which cuts the conglomerate. In some instances a granite dike was found to cut some of the large bowlders of the conglomerate, when the contact between the dike and the granite bowlders could not easily be determined. The exact relations of the hornblende-granite and the augite-granite to each other, and the relations of the latter to the sedimentaries, are still doubtful. The gray granite has not been found in contact with the schists, argillites and conglomerates, and it is cut by the red granite, which also cuts the schist. The hornblende-schists and mica-schists of Snowbank and White Iron Lakes grade into argillaceous slates and conglomerates, the schistose character being most fully developed at the contact with the granite.

The Animikie actinolite-magnetite-schists are derived from rock containing an original iron carbonate. As the formation thins out toward the east, and passes under the gabbro, it becomes more crystalline. Near the contact of the gabbro augite and olivine occur intimately associated with the actinolite and magnetite of the Animikie schists. The black slates have been changed into biotite-schist in the proximity of the gabbro. These slates disappear before the Dunke River is reached, having been removed at the time of the gabbro intru-

[1] Preliminary Report of Field Work during 1893 in Northeastern Minnesota, by A. H. ELFTMAN. Geol. and Nat. Hist. Sur. of Minn., 22d Ann. Rep., Part XII, pp. 141–180, 1894.

sion. The Pewabic quartzite at the bottom of the Animikie decreases in thickness as Birch Lake is approached from the west, and in the vicinity of Iron Lake disappears entirely. From this locality eastward the iron-bearing rock rests upon the granite. It is concluded that the Pewabic quartzite between Birch Lake and Gunflint Lake belongs to the middle iron-bearing member of the Animikie.

In Ts. 62 N. and 61 N., Rs. 10 W. and 11 W., occurs a heavily bedded olivine gabbro. In going from the northern and southern limits of the gabbro toward the center of the area it is noticeable that the ferro-magnesian minerals decrease and the feldspar increases in proportion, until in the center of the mass occur numerous knobs and areas, a mile or more in extent, composed of plagioclase rock or anorthosite, which are regarded as segregations. In the center of the mass the rock has greater coarseness of texture, and also more of a stratified appearance, arising from the arrangement of the constituent minerals in bands. The mineral and chemical composition of the various parts of the formation correspond to the known rules which govern the cooling of liquid magmas, and the whole is regarded as a batholitic intrusion rather than a surface flow.

Red rocks, comprising augite-syenite, quartz-porphyry, felsite, etc., occur in the vicinity of Greenwood Lake, and were followed to the shores of Lake Superior, making together one prominent group of rocks.

The dark gabbros of Irving, the diabases and the amygdaloids are placed in another group, called the diabase group. The anorthosites of the coast of Lake Superior, described by Lawson as pre-Keweenawan, and newly discovered masses back from the coast, are found to be detached blocks from the great gabbro mass enclosed in and underlain by the black gabbro, as previously held by Irving and Winchell. The latter rock is considered as the effusive equivalent of the great basal gabbro. After the aggregations of feldspar had separated from the gabbro magma, and were floating around in it, they were ejected in portions of the unsolidified magma, and being lighter than it, floated near the surface, and are found only near the top of the first outburst of lava or black gabbro. Later, when the rock was somewhat eroded, the feldspar knobs projected above the surrounding rocks, and later were covered by the flows of the red rock group. Therefore, the conclusion of Lawson that the anorthosite forms a pre-Keweenawan terrane, is rendered valueless.

In chronological order the Keweenawan of the north shore of Lake Superior can be divided into gabbro, diabase, red rocks and later dikes.

Grant,[1] in 1894, describes the lowest beds of Grand Portage Island, north coast of Lake Superior, as consisting of arenaceous slates, sandstones and conglomerates, the fragments of the latter being quartz, quartzite, siliceous slate, a dark flinty rock, red quartz-porphyry and red granite. These are in part clearly waterworn. All of the pebbles of the conglomerate can be matched in the Animikie strata near by. These beds are regarded as the lowest of the Keweenawan in this locality, and the material in the conglomerate shows that the Animikie clastics had been subjected to metamorphosing forces before Keweenawan time, and, as agreed by all Lake Superior geologists, that there was an erosion interval between the two. As the red quartz porphyry and the granite have been shown to be intrusive in the Animikie, and also in the gabbro and diabase of Pigeon Point and Grand Portage, it is concluded that these intrusions occurred at a date later than the Keweenawan.

COMMENTS.

It is to be presumed that this last statement applies only to the Keweenawan of the locality discussed.

Lawson,[2] in 1893, describes a multiple diabase dike near the mouth of White Gravel River on the northeast coast of Lake Superior, where occur in a breadth of fourteen feet no less than twenty-eight vertically intrusive sheets of diabase, ranging in thickness from one inch to six and one-half inches, separated by twenty-seven sheets of granite, ranging in thickness from a quarter of an inch to eight inches. The dikes anastomose and are connected at various places, showing that they are due to a single intrusion. The granite is seemingly homogeneous, there being no differentiation of structure or of mineral composition. It is believed that the splitting of the granite was due directly to the invasion of the diabase magma. This occurrence is comparable to the complex parallel invasion of the schistose rocks of the Ontarian system by granite.

[1] Note on the Keweenawan Rocks of Grand Portage Island, North Coast of Lake Superior, by U. S. GRANT. Am. Geol., Vol. XIII., No. 6, pp. 437–438, 1894.

[2] Multiple Diabase Dike, by A. C. LAWSON. Am. Geol., Vol. XIII., No. 5, pp. 293–296, May, 1894.

Spurr,[1] in 1894, gives an account of the rocks of the Mesabi district, and particularly of the iron-bearing rocks.

The oldest formation of the district is the Keewatin, the most common rock of which is green schist, but associated with this, especially near the granites, are hornblende-schists and mica-schists. The schists have a regional cleavage, which is nearly uniform in trend, about N. 70° E. and nearly vertical. Next in age to the Keewatin schists is the hornblende-granite of the Giants Range. This range has an average width of about ten miles, and its direction is the same as that of the schistosity of the Keewatin rocks. The granite is intrusive in the schists, as shown by numerous fragments imbedded in it, by stringers of the granite in the schists, and the metamorphism of the schists adjacent to the granite.

Unconformably upon the former is the Animikie series. The Animikie series has no marked folding, slaty cleavage or schistose structure. The rocks of the series are in a gentle southern monocline, in a direction perhaps 10° or 15° East of South. This monocline has gentle undulations, with axes parallel to its dip, and in the Virginia area has been faulted. The amount of disturbance is greater adjacent to the central part of the district, where are found the Keweenawan rocks. It is probable that the weight of the Keweenawan rocks has produced a sinking in the area south of the Animikie, and that this has produced the tilting. The Animikie series may be divided into three chief members: the Pewabic quartzite, the iron-bearing member and the upper slates. The Pewabic quartzite is a fragmental rock, indurated by the enlargement of quartz grains. It occasionally passes into a fine-grained conglomerate. The iron-bearing member is composed of peculiar rocks, presenting no resemblance to the Pewabic quartzite or to the upper slate. The upper slates are of great thickness, and have at their base an impure limestone, often dolomitized or sideritized.

The part of the iron-bearing member from Pokegama Falls to Embarass Lake is called the Western Mesabi range, that from Embarass Lake to Gunflint Lake, the Eastern Mesabi range, and from Gunflint Lake east, the International Boundary area. The description of the iron-bearing member below applies to the western part of the district. It has a thickness varying from 500 to 1000 feet, with an average of about 800 feet. The dip varies from less than 10° to as much as 30°,

[1] The Iron-bearing Rocks of the Mesabi Range in Minnesota, by J. EDWARD SPURR. Geol. and Nat. Hist. Sur. of Minn., Bull. X., p. 268, with geol. maps, 1894.

the width of the formation varying correspondingly from two or three miles to less than half a mile, the average width being one mile, and the average dip 10°. Resting upon the iron-bearing member is a great thickness of fine-grained slates, at the base of which is locally an impure dolomitic limestone. When this limestone is present, the contact between the iron-bearing member and upper slate cannot be distinctly located.

The least altered phase of the iron-bearing member is a rock called taconyte, which consists of a background of cryptocrystalline, phenocrystalline and chalcedonic silica, in which are numerous granules. These are composed of glauconite, siderite, hematite, magnetite, limonite and cryptocrystalline silica, in the very freshest phase the two former being predominant. The granules in one of these fresher phases by analyses showed about 35 per cent. of siderite and 65 per cent. of glauconite, or about 22 per cent. of ferrous oxide in the form of siderite; and about 10 per cent. of ferrous and ferric oxide, two-thirds being the former in the glauconite. Other analyses gave similar results. Analyses showed a very little calcium and magnesium. In the freshest phase found were seen, in thin section, probably detrital original grains of carbonate, recognized by their cleavage as calcite or dolomite. From the taconyte, by a complicated series of metasomatic changes, there have developed cherts and jaspers, which are sideritic, hematitic, magnetitic or actinolitic, or two or more of these combined. During the process the chert and iron oxides were largely concentrated in alternating bands. The cherts and jaspers are frequently concretionary and brecciated. They have often a prismatic jointing and horizontal parting.

These transformations were caused by downward percolating waters, carrying as the chief agents oxygen and carbonic acid, and as subordinate agents sulphuric acid and alkalies. In the changes from glauconite and siderite to the oxides, there was an important shrinkage of the mass, and this has resulted in the brecciation, prismatic jointing horizontal parting and banding. The prismatic jointing is analogous in its formation to the shrinkage of basaltic columns of lava. The horizontal parting is caused by a later shrinkage along the least diameters of the columns formed by the prismatic jointing. The banding is due to the removal of silica and the entrance of iron along the parting.

The ore deposits rests upon the Pewabic quartzite, or upon the

hard and little altered iron-bearing rock, in areas of especial weakness or disturbance, as (1) actual fault lines, (2) incipient fault lines, (3) apices of anticlinal folds, and the troughs of synclines. These are places of fracture and where abundant waters were converged, often form wide areas, and therefore where large quantities of iron were supplied. The downward percolating water, taking iron carbonate in solution, precipitated the iron as oxide in those places where there was an abundance of oxygen, and at the same time took the silica in solution, thus forming the ore bodies. Between those of the largest size and the small local concentrations there are all gradations. The larger deposits of ore occur where they are protected from glacial erosion on the north by a hard ridge of the Keewatin rocks, and especially when the hard rocks give slight elevations on either side, so as to present a basin-like depression.

The glauconite in origin is believed to be the same as modern glauconites, that is, it has developed within foraminifera and other minute shells, as a result of a reaction between the organic matter within the shells and fine ferriferous clay. As the formation contains only a small quantity of ordinary fragmental quartz grains, it formed in water at a depth beyond which much of these material was deposited. As its upper horizon grades into limestone, this indicates a further subsidence of the area, so that the distance from the shore line became so great that very little mechanical detritus was furnished, and the deposit was made up of calcareous matter.

In the eastern Mesabi district the Animikie strata are pierced and intermingled with the northern border of the Keweenawan rocks, so that their normal attitude is often much disturbed. With this change the iron of the iron-bearing member becomes largely magnetic and the silica hard and crystalline. It is concluded that the iron before Keweenawan time was here in the state of sesquioxide, and that the heat of the igneous Keweenawan rocks and the disturbances of the Animikie series produced by them are the causes of the change of the sesquioxide of iron to its magnetic form. Thus the normal process of decomposition and concentration was brought to a close, and this probably explains the poverty of this part of the district in large ore deposits.

At the base of the Cretaceous are ferriferous detrital deposits derived from the Animikie. A study of these indicates that the metasomatic processes had gone far before Cretaceous time, although they have since continued to the present time.

COMMENTS.

This account of the Mesabi district is fairly satisfactory. The discovery of a large amount of glauconite in the least altered phase of the iron-bearing rock is an important additional point in the genesis of the rocks of the iron-bearing formations of the Lake Superior region. However, the conclusion that all of the iron of the iron-bearing formation, even in the Mesabi district, is derived from glauconite hardly seems established. In the least altered phase of the rocks, one which shows comparatively little or no evidence of change, according to the analyses given, a larger proportion of the iron is in the form of siderite than in the form of glauconite. Also in the least altered phase of rock, what were regarded as original detrital grains of calcite or dolomite were seen. These were taken to be one of these minerals from their cleavage, but as the cleavage of siderite is of an identical character, and as the analyses of the least altered phases of the rock show abundant siderite, and but a minute quantity of magnesium and calcium, it seems far more probable that this original material is siderite. There is no reason, so far as the writer can see, why a part of the iron should not have formed as siderite, and another part as glauconite, even in the Mesabi district itself, and it is wholly possible that in the Lake Superior region, in the Upper Huronian of which the Animikie is a part, in one district glauconite may have been the predominant form, while in another siderite was the more abundant.

It is of interest to note that the succession of rocks in the Mesabi district is the same as previously determined in the Penokee district and that the processes of development of the various phases of the altered ferruginous rocks, the agents which did the work, the resultant types and the concentration of the ore bodies, as given for the Mesabi district, are remarkably similar to those which have been ascertained to apply to other districts of the Lake Superior region.[1] The frequent presence of the ores in basins is regarded as due to the more resistant character of the surrounding Keewatin rocks, rather than to

[1] The Penokee Iron-bearing Series of Michigan and Wisconsin, by ROLAND DUER IRVING and CHARLES RICHARD VAN HISE. Tenth An. Rep., U. S. G. S., Chap. V., pp. 347–458, 1890, and Mon. XIX., U. S. G. S., Chap. V., pp. 182–295, 1892.

The Iron Ores of the Lake Superior Region, by C. R. VAN HISE. Trans. Wis. Acad. Sci., Arts and Letters, Vol. VIII., pp. 219–223, December 1891.

The Iron Ores of the Marquette District of Michigan, by C. R. VAN HISE. Am. Jour. Sci., Vol. XLIII., pp. 116–132, February 1892.

their original concentration in such places. The fact that the southern dipping monclinals are folded into a series of slight anticlines and synclines, combined with the presence of iron ore in basins, seems to me to be strong evidence that many if not all the larger ore bodies in the Mesabi district as elsewhere were concentrated in pitching synclinal troughs. The recent development of the mines confirm this conclusion and give no evidence that the large ore deposits have formed at anti-clines or faults. The following laws, worked out in reference to the other districts of the Lake Superior region, appear also to apply to the Mesabi district, and if so, they may be said to be universal for this region.

(1) The iron ores always rest upon a relatively impervious basement. This basement may be a shale, a slate, a quartzite, an amygdaloid, a volcanic tuff, an intrusive mass or a dike, a less porous layer of the iron-bearing formation, or any combination of these. (2) Large ore bodies are chiefly found where the impervious basements, simple or complex, form pitching troughs. (3) These pitching troughs are particularly likely to bear unusually large ore bodies when the iron-bearing formation has been brecciated or shattered by folding or some other process, so as to allow ready entrance to percolating waters. Within the troughs the iron-bearing and oxygen-bearing solutions have been converged and mingled, thus precipitating the iron oxide.

Spurr,[1] in 1894, discusses the stratigraphic position of the Thompson slates of northeastern Minnesota. These have heretofore been correlated with the Animikie slates. However, almost every phase of slate of the Thompson series can be duplicated by the less altered phases of the Keewatin schists of the Mesabi range. In the vicinity of the Mississippi River the Thompson series becomes partly crystalline, being changed into sericitic, micaceous, hornblendic, staurolitic or garnetiferous schists which correspond exactly with the green schists of the Keewatin. The cleavage of the Thompson series marks a distinctively pre-Animikie disturbance. The trend of the cleavage corresponds with that of the schistosity of the Keewatin of the Mesabi range, and it is thought that the two were developed at the same time. The Thompson series has undergone a considerable folding, and in this respect also more resembles the Keewatin than the Animikie slates,

[1] The Stratigraphic Position of the Thompson Slates, by J. E. SPURR. Am. Jour. Sci., Vol. XLVIII., No. 294, pp. 159–165, August 1894.

which are in an undisturbed condition. The Thompson series is therefore regarded as unconformably below the Animikie, and is provisionally correlated with the Keewatin.

COMMENTS.

No petrographical descriptions are given of the Thompson slate and of the Keweenawan green schists which are said to be similar. The essential likeness or unlikeness of such fine-grained rocks as the Thompson slates and the Keewatin green schists can only be ascertained by microscopical studies. The Thompson slates with the microscope are seen to be little altered fragmental rocks, while the green schists of the Mesabi range are thoroughly crystalline, and in many places altered volcanic rocks. Further, the crystalline schists of the Mississippi River are not connected by continuous exposure with the Thompson slates, and may belong to a different series from them. Certainly a much more thorough study of the problem is required before it can be considered as probable that Irving was wrong in placing the Thompson slates as a part of the Animikie series.

C. R. VAN HISE.